Science for saving species

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Climate change and threatened species

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Threatened Species Recovery Hub

National Environmental Science Programme

IMAGE: BY NICOLAS RAKOTOPARE

Droughts, heatwaves, floods and fires

Threatened species in a changing world

The world is changing. Some of this change is planned and desirable. But much else is an unwanted consequence of the expansion of the human species. Those unwanted impacts will affect our lives and those of our descendants. But they are also affecting – and will increasingly threaten – many of the world's endangered species, including many Australian plants, animals and ecosystems.

The Australian environment is now experiencing climate change. Of course, not all single abnormal climate events are a consequence of our pattern of greenhouse gas emissions. But the pattern is evident.

Extremes becoming the new normal

In the past 12 months, fires without recent precedent occurred from the mountain rainforests of Queensland to the World Heritage alpine heathlands and rainforests of south-western Tasmania. Unusually long periods of extreme heat baked much of inland and eastern Australia. The long drought intensified across much of inland Australia. Exacerbated by unsustainable water management, hundreds of thousands of fish, including the Vulnerable Murray cod and the Critically Endangered silver perch, have died in the Menindee Lakes and the lower Darling River. Increasingly frequent and extensive bleaching events – driven by unusually warmed waters – damage our coral reef systems. In the Australian Alps, the intricate interconnections among species fray as the region warms and snow cover diminishes. The thread connecting these very different examples of loss is climate change.

Perhaps we imagined that the impacts of climate change will be felt mostly in far-flung polar regions with melting ice caps – but not here at home. However, the recent biodiversity losses across many parts of Australia demonstrate that the changes will also happen far closer to home. Much of Australia's nature, the essence of our country, is susceptible to climate change. Indeed, the loss in the last decade of Australia's Bramble Cay melomys may be one of the first cases in the world of extinction due to climate change.

IMAGE: VICKI NUNN, PUBLIC DOMAIN

The 2010 flood of the Calliope River in central Queensland.

Catastrophic losses

A sobering and acute example is of the mass mortality over a few days of extreme heat for the now Endangered spectacled flying-fox. Reports indicate that up to one-third of the total Australian population of this species succumbed to the extremely hot temperatures over just two days in late 2018. Episodes of such extreme heat, and consequent mortality, are becoming more frequent. We cannot expect this to stay a single 'freak' event. Many other (less conspicuous) threatened species are also likely to have experienced acute population losses but without such public awareness.

Many other precariously imperilled species have the odds tipped further against them by climate change, and it is likely to exacerbate other threats. Recent fires have threatened the tiny remaining ranges (and tenuous populations) of three of Australia's most Critically Endangered species, the Gilbert's potoroo and western ground parrot in south-western Australia, and the central rock-rat

Inside the Summer 2019 issue of *Science for Saving Species*

Threatened Species Recovery Hub

National Environmental Science Programme in a few mountaintops in central Australia. At least for south-western Australia, the likelihood and menace of these fires is being magnified by an increasingly drier climate.

Incremental impacts are also a danger

Large sudden catastrophic events like the Menindee Lakes fish deaths confront us but, in many cases, climate change impacts operate incrementally and insidiously. For decades rainfall in south-western Australia has been decreasing and with it the swamps of the western swamp turtle dry for longer periods each year. In the future there may not be enough wet months each year to allow the turtles to eat, grow and reproduce before the swamps dry up.

Humans suffer as a consequence of climate change. But, to an extent, we can respond, such as by using air-conditioning and more water, further exacerbating the unwanted environmental consequences. Most threatened plants, animals and ecosystems have less capacity to cope. It is largely our actions that have caused their declines; increasingly, it will be up to us to prevent their extinctions. We are now witnessing degradation of Australian biodiversity as a consequence of climate change. But this is just the beginning: it will get worse. The momentum, pervasiveness and complex manifestations of climate change will increase the need for our actions, but render the response increasingly challenging.

Responding to the challenge

But the challenge must be faced, for otherwise we will lose our nature, and much else. There are many things we can and should do. Our governments have committed to greenhouse gas reductions, and instituted some mechanisms to achieve these targets. But this is a gradational response. The equations are straightforward: the more we rein in emissions, the less will be the environmental loss and the impacts to the lives of our children, and those of their descendants. We can and should be ambitious and strategic in reducing emissions and tackling this global problem.

Helping nature to cope

We need to reverse the ongoing losses of habitat due to vegetation clearance. In a new world buffeted by climate change, many species may persist only if they can disperse to cooler, wetter or more equitable locations, or to unburnt areas after extensive fire. We can give such climate refugee species more of a chance by restoring habitat connectivity; but even more so by halting land clearance.

The aftermath of the 2016 fire in the world heritage area on Tasmania's central plateau.

We can and should identify, and then stringently protect and carefully manage, those special and critical parts of the landscape that give refuge to species at times of short- and longer-term climatic stress. Research in this hub is doing much to recognise such refugial areas. For some species, we will need to actively intervene and translocate populations to such relatively secure areas or to areas more likely to support favourable climatic conditions in the future, as is now being trialled for the Critically Endangered western swamp turtle.

We can strengthen environmental laws and policies, such that they are not set aside or abused when humans face their own crises due to climate change. We can establish more precautionary buffers for use of natural resources such as water, to ensure that our resource use, particularly in periods of stress, does not lead to irreversible collapse of the environmental systems on which we depend.

As a concerned society, with a stake in the future, we should ensure that laws and processes governing developments appropriately factor in climate change considerations. The recent case of a ruling against a New South Wales coal mine, which included climate change impacts as one of the deciding factors, is a heartening precedent.

The world is changing.
We can help shape that change.

Professor John Woinarski
Deputy Director, TSR Hub
John.Woinarski@cdu.edu.au

Further reading

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The ghosts of **digging mammals past**

Native digging mammal species used to occur throughout Australian landscapes. Many are now missing. IMAGE: LEONIE VALENTINE

Once upon a time, not that long ago, Australia hosted an abundance of digging mammals like boodies, bilbies and potoroos. With the loss of these species from many parts of the landscape comes the loss of the work they did as ecosystem engineers. **Leonie Valentine, Bryony Palmer** and **Gabrielle Beca** unearth some important findings about the importance and role of native digging mammals in the Australian landscape and things to consider when returning lost diggers to their homelands.

From subterranean marsupial moles to hairy-nosed wombats, digging mammals once occurred right across the Australian mainland, and on many islands. However, over the past 200 years, most of Australia's unique digging mammals have undergone drastic population reductions and range declines due to habitat loss, predation by cats and foxes and altered fire regimes. Species like the boodie (or burrowing bettong, *Bettongia lesueur*) were previously widespread, but are now found only on offshore islands like Barrow Island or in fenced conservation reserves where they have been reintroduced. Other species, like the lesser bilby (*Macrotis leucura*) and pig-footed bandicoot (*Chaeropus ecaudatus*), were considered common by Indigenous Australians and early Europeans but are now gone forever.

The quenda (*Isoodon fusciventer*) is a digging bandicoot endemic to south-western Australia.

IMAGE: LEONIE VALENTINE

Why are digging mammals important?

By creating burrows for shelter, ploughing through soil or digging foraging pits when searching for food, mammals (and other animals) move and rework soils, a process known as bioturbation. Although the digging activities of some mammals appear small at a local scale, their cumulative impact can be surprisingly important for broader-scale landscape processes. Consequently, many of Australia's digging mammals are considered ecosystem engineers. But many digging mammals are now absent from much of their former range. Without them, the ecosystem functions these animals once provided are no longer taking place. This may be compromising landscape health by reducing key processes such as soil turnover, water infiltration, nutrient cycling and plant recruitment.

What about the rabbit?

The European rabbit, an introduced digging mammal, has spread throughout many Australian landscapes. This invasive species, with its ability to procreate rapidly and proclivity to overgraze, has caused enormous ecological damage and been the subject of many control programs. But could the rabbit be an ecological replacement for our lost native diggers? Unfortunately, it seems unlikely. Despite being considered an important ecosystem engineer in its native range, research on its impact in Australia

IMAGE: LEONIE VALENTINE

Quenda create many foraging pits while searching for underground invertebrates, tubers and fungi.

strongly suggests that they are not functionally equivalent to our native digging mammals.

Quenda and woylie as diggers

To better understand the roles of Australian digging mammals, we have been examining what some of the persisting species can do.

A frequently spotted native digging mammal in Perth bushland reserves is the quenda (*Isoodon fusciventer*). Like other bandicoots, the quenda has suffered range contractions and population declines, but it persists in some urban bushlands and has been reintroduced to others, such as Craigie Bushland (managed by the City of Joondalup).

Reduced to 1% of its former range, the woylie is still found at proposed Dryandra Woodland National Park, in south-west Western Australia.

The boodie is a bettong that was previously widespread but is now listed as Vulnerable.

Quenda use their well-developed fore-limbs to dig for underground food, such as invertebrates, fungi and tubers, turning over substantial amounts of soil in the process. Through the creation of foraging pits, quenda break the crust of the soil surface, which changes the ability of soil to repel water. The combination of digging and discarding soil exposes subsurface soil and buries organic matter and litter under the spoil heap, potentially helping litter decomposition.

We've recorded higher levels of soil properties important for plant growth, such as potassium and electrical conductivity, in the spoil heaps created by quenda than in undug soil. These extra nutrients may assist seedling growth. In a trial, the seedlings of a local eucalypt, tuart (*Eucalyptus gomphocephala*), grew faster and bigger in soil from quenda spoil heaps than seedlings grown in undug soil.

Previously occurring across much of southern Australia, the woylie (or brush-tailed bettong, *Bettongia penicillata*), is now restricted to just 1% of the mainland and is listed as Critically Endangered. This delightful digging mammal still occurs in the proposed Dryandra Woodland National Park, an unfenced reserve approximately 170 km south-east of Perth. Woylies are also ecosystem engineers, turning over vast amounts of soil while digging for their dinner (mostly fungi, roots and seeds). They may also play an important role in the dispersal of some plant species, such as sandalwood (*Santalum spicatum*), through seed-caching behaviours. We are investigating their effect on both soil properties and seed dispersal.

Returning lost diggers

Digging mammals are now absent from vast areas of the country. To improve the conservation status of these species, many conservation organisations, including Australian Wildlife Conservancy and Western Australia's Department of Biodiversity, Conservation and Attractions, are working to reintroduce them to selected areas – usually behind predator-proof fences or on predator-free islands.

Reintroducing digging mammals could help to restore or reinvigorate lost ecosystem functions but the landscapes these animals are being reintroduced into are very different to when they were last present. Many native species are missing or reduced in abundance, new species of plants and animals are present, vegetation communities have been restructured by altered fire regimes and grazing by sheep or cattle, and the functions that the boodie itself contributed to have been reduced.

In this new landscape, how would the cumulative effects of thousands of foraging pits and burrows of species like boodies alter soil properties and structure vegetation communities? To find out, we are measuring soil properties and quantifying plant abundance and species composition on and off boodie warrens to see how they differ from undisturbed areas. We'll then assess the same variables across large areas with and without boodies, and other digging mammals, to see what happens when the ghosts of diggers past are returned to Australian landscapes.

Read more:

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For further information

Leonie Valentine
leonie.valentine@uwa.edu.au

BELOW: Boodies create extensive underground warrens, with multiple entrances. Bryony Palmer examines how soil manipulation by boodies alters soil and plant properties at Yookamurra Sanctuary (Australian Wildlife Conservancy) where they have been reintroduced.

Talking night parrots on Paruku Country

IMAGE: STEVE MURPHY

IMAGE: JAANA DIELENBERG

Paruku Indigenous Rangers and elders recently hosted a workshop on night parrots for other rangers and conservation groups from the southern Kimberley and northern Western Deserts. The TSR Hub's **Nick Leseberg** from The University of Queensland went along to learn from the rangers about the night parrot population in the Great Sandy Desert, the Paruku Rangers' work with the bird, and to share findings from his research on the bird in western Queensland.

ABOVE: The workshop was attended by elders, rangers or their representatives from Paruku, Ngurrura, Ngururrpa, Ngurra Kayanta, Kija, Nyikina Mangala, Nyangumarta, Karajarri and Kiwirrkurra, as well as KLC staff, and scientists from the TSR Hub, WA DBCA, Environs Kimberley, the BBO and WWF.

The Paruku Rangers, supported by the Kimberley Land Council, have achieved something few people in Australia have. Since mid-2017, Ranger Coordinator Jamie Brown, and rangers Abraham Clayon, Lachlan Johns and Hanson Pye have confirmed (now multiple times) the presence of night parrots in the Great Sandy Desert.

Finding the endangered nocturnal parrots the first time was a collaborative effort between Paruku Rangers, Paruku Indigenous Protected Area (IPA), the Kimberley Land Council, WWF Australia and Environs Kimberley. Together they analysed very old records from the region, identified potential habitat and spoke to elders. Confirmation came during fauna surveys, when a camera trap image and then an audio recording were captured.

Discovering the bird on their country has opened up new opportunities for the Paruku Rangers, including receiving a grant from the Australian Government's Threatened Species Commissioner to manage threats to the bird, including fire and feral cats. Other Indigenous groups in the Kimberley and Central Deserts may also have the rare and elusive bird on their country and are interested to learn more about it.

The location of the workshop was the Handover Site, a patch of scattered woodland close to the shores of Lake Gregory, where Tjurabalan Native Title was handed down. The lake shimmering in the distance and covered in thousands of water birds provided a spectacular backdrop to the workshop. The heat of late October (45C in the shade) was no deterrent to the enthusiasm of Rangers and Traditional Owners from nine different Native Title groups who attended the workshop. They came to share information about the bird and the best ways to detect, monitor and care for it.

Insights from Paruku elders showed that the bird has been heard in the region in past decades. Some of the old people recognised the sound of the call when it was played

BELOW: Paruku Ranger Coordinator Jamie Brown (centre) leading fire management discussion at the workshop. L-R: Paruku Rangers Abrahm Clayon and Lachlan Johns, Jamie Brown, Alexander Watson from WWF Australia and Malcolm Lindsay from Environs Kimberley.

IMAGE: JAANA DIELENBERG

to them and could recall where they had heard it as children. Rangers from other groups attending were enthusiastic to take recordings of the calls back to play to their own old people. This may yield valuable information on former (and possibly still active) night parrot locations.

The workshop was also an opportunity to exchange information with scientists from other regions who are also studying the rare and elusive bird. Nick Leseberg's research in western Queensland is improving understanding of the parrot's preferred habitat, what threats impact their populations, and how those threats can be managed. Nick was able to share his findings with the rangers and to provide some training on the use of acoustic monitoring and analysis. Other scientists from the Broome Bird Observatory and Western Australia's Department of Biodiversity, Conservation and Attractions also shared insights gained from other populations.

The information exchange allowed the Indigenous Rangers to understand the ecology of the bird based on research in other parts of the country, while helping scientists understand the landscape in which the birds are likely to occur in Western Australia. The discussions also covered the opportunities presented by collaborations.

According to Nick Leseberg, a general difficulty of night parrot research is the very remote locations in which the birds occur, and the amount of effort required to conduct systematic surveys.

"Local people armed with good knowledge about the bird are our best opportunity to find new populations in this very vast region," Nick said.

"Rangers are in the best position to detect new populations. They know their country. Once we shared information on where the birds are likely to be found and the habitat they use, you could see the Rangers immediately thinking about where on their country these sites might be. By the end of the workshop, some of the Rangers had already decided exactly where they were going to search for night parrots."

IMAGE: JAANA DIELENBERG

ABOVE: Hub researcher Nick Leseberg showing rangers how to use acoustic analysis software to check audio data collected by automated recording devices.

As a scientist studying the bird, Nick found a site visit to where Paruku Rangers had found the bird incredibly valuable.

"Before the Paruku Rangers found these birds there were only two sites in the world where we were certain the bird occurs. This meant there was a risk that any conclusions we make about the bird's ecology and habitat preferences were biased by that small sample size. Seeing where the birds occur on Paruku country was extremely valuable, because it corroborated the conceptual models we have been developing based on our research at the other two sites. We can now be more confident that our predictions about where the bird might be found are valid."

The TSR Hub is now working with Paruku Rangers and other workshop partners to develop more resources for ranger groups to raise awareness about the bird and on how to search for night parrots and manage potential habitat.

The workshop was also an opportunity for the TSR Hub to share information on other hub research projects, such as the Arid Zone Monitoring project, which is working with groups across Australia's deserts to collate tracking surveys.

For further information

Nick Leseberg
n.leseberg@uq.edu.au

Zack Wundke
zack.wundke@klc.org.au

"Late last year, our team of Paruku rangers, we captured a picture of the night parrot here in the Great Sandy Desert. It was really exciting for us. Now we want to share what we've learned with scientists and with the other Indigenous Ranger groups.

So in October we had the first on-country Kimberley night parrot workshop. We hosted it here in Mulan, at Lake Paruku. We all got together, sharing stories of the experiences with working on the night parrot and sharing ideas on how to manage and protect the bird and its habitat. Some guests came a really long way.

If you ever come across sightings or sounds and you're on an IPA, please respect our rules. If you do find it, just come let one of us Rangers know. That would be good so we could go and have a look there in that area where you may have seen it or heard it.

I'd also thank our elders for supporting us through this journey with the night parrot and managing and protecting the animal here on Paruku."

Jamie Brown
Head Paruku Ranger

IMAGE: JAANA DIELENBERG

Gimme shelter: **Conserving hollow-nesting birds**

RIGHT: Larger-bodied birds, such as this little corella, need larger tree cavities, a rare resource in many human-altered habitats.

What influences where birds choose to nest? About 15% of Australian birds, or 114 species, need tree hollows for breeding or shelter. The number of hollow-bearing trees is declining due to timber harvesting and development, and competition is stiff in the animal world for these increasingly rare tree hollows. Non-native species and increasing urban numbers of natives such as rainbow lorikeets are changing the community dynamics of hollow-nesting species. Critical to conserving the range of hollow-nesting native birds is understanding how these interactions operate when it comes to who gets to nest and where. This has been the topic of **Andrew Rogers' PhD research at The University of Queensland**. He explains how his research on the drivers of nesting competition can help us effectively manage invasive hollow-nesting species and improve the outlook for threatened native ones.

Hollows for habitat

Australian hollow-nesting birds are opportunistic users of tree hollows. Unlike woodpeckers found in much of the rest of the world, they don't excavate their own cavities in living tree wood. Instead, the hollows they use for shelter and nesting are created by termites or fungal decay. The downside to this is how slowly these natural tree hollows form. Everywhere in Australia, trees bearing habitable hollows tend to be large and old – mountain ash trees from the Victorian Central Highlands, for example, don't begin to develop cavities for approximately 120 years. Losing them to land-clearing for agriculture and urbanisation has meant a sometimes devastating loss of habitat for hollow-dependent species.

Predation and competition

Added to this loss of habitat are the twin threats of predation on nesting birds and competition for hollows by invasive species. Understanding these interactions between invasive and native species has been the focus of my research. If we are to effectively manage invasive species for the benefit of native species, we need a better grasp of the where and how of native–invasive interactions than we currently have. It can be tricky to quantify direct and indirect interactions. It requires a lot of time in the field observing, and even then we can rarely capture the big picture of community-wide interactions. In addition, species that are widespread throw

LEFT: A common myna sits at the entrance to a tree hollow. While the common myna can nest in buildings and other artificial structures, they can also compete for natural tree hollows in and around large urban trees.

RIGHT: A rainbow lorikeet squeezes out of a tree hollow. Cavity entrance size is important for hollow-nesting birds as it limits access to the nest of other, competitor and predator, species.


IMAGE: A. ROGERS

up particular challenges for data collection, as native–invasive interactions are likely to differ across habitats and across communities with varying compositions of native species.

In response to these challenges, my research combined data on animal behaviour collected in the field with models of competition to see if we can better predict where and when invasive hollow-dependent birds are likely to be having an impact on native bird species.

Hollow nesting success: The ins and outs

I used this combination of field data and modelling to assess the impact of competition on the nesting dynamics of Brisbane's hollow-dependent birds. Of the 114 Australian bird species (approximately 15% of the total) that need tree hollows for breeding or shelter, 46 are listed as threatened. There are around 48 cavity-nesting birds found in south-east Queensland or the greater Brisbane area.

My research used a combination of artificial nest boxes and behavioural observations around natural tree hollows to investigate where certain species nest and what influences nesting success. While the nest site requirements are broadly known for many species, for many others we still don't have a good idea of where they nest and how competition influences their ability to nest in certain habitats. For example, while many hollow-nesting species of birds are declining in urban areas, rainbow lorikeets have increased in numbers and are now one of the most common urban birds in Brisbane. Despite this, we don't know where most of these birds breed, and how their increasing numbers have changed the community dynamics. Similarly, the addition of invasive species is also likely to have driven changes in the nesting dynamics of hollow-breeding communities, and the challenge is to predict how such introductions have or will change species interactions at the community level.

Invasions and interactions

Across Australia there are seven invasive hollow-breeding bird species, and an additional 15 Australian hollow-breeders that have been moved outside their historic range – but most of these have not yet been studied in the field. This is the case in Tasmania, where I reviewed the potential impacts of introduced birds. I found that the seven non-native species, representing 27% of the total hollow-nesting bird community, are likely to be competing with 65% of the native hollow-nesting birds. This makes Tasmania one of the most invaded places in Australia.

Several endemic and common species are likely to be impacted by introduced birds, but the consequences for their long-term population trends needs further research. With limited funds for monitoring, most studies of invasive species impacts have been necessarily restricted to just a few interacting species.

However, we hope that our work on the drivers of competition means we can model the consequences of invasive species introductions for entire hollow-breeding communities, and so improve the lot of our native hollow-dependent birds.

For further information

Andrew Rogers
a.rogers@uq.edu.au

BELOW: Amelie Genay and Andrew Rogers monitoring nest boxes set up for cavity breeding birds around Brisbane. The boxes were used by six native species, including birds and mammals, as well as the invasive common myna.


IMAGE: C. ARCHIBALD

Case study: Common (or Indian) myna

The common myna is one of Australia's most widespread invasive birds and it is a hollow nester. It occurs along most of the east coast and has the potential to establish in Western Australia and Tasmania. Despite this large range, most studies on its impact have come from the Canberra, Sydney and Newcastle areas. By examining its preferences for nest sites, including tree hollows, and comparing those to native species we can help identify where it's likely to compete with native species, and explore the underlying drivers of competition between all hollow-nesting birds.

Our work has shown that the common myna and other introduced hollow-nesters have significantly increased competition for nesting sites. Approaches like this one that we have developed for the myna can be explored for native threatened and vulnerable species to identify where competition could be impacting reproductive success, and help prioritise future field work.

Jabin Watson beside the flume.

IMAGE: NICOLAS RAKOTOPARE

How did the fish cross the road?

A new innovation to get fish past culverts

Fish need to move to find food, escape predators and reach suitable habitat for reproduction. Too often, however, human activities get in the way. Dams, weirs and culverts (the tunnels and drains often found under roads) can create barriers that fragment habitats, isolating fish populations. An Australian innovation, however, promises to help dwindling fish populations in Australia and worldwide. Our solution, recently described in *Ecological Engineering,* tackles one of the greatest impediments to fish migration in Australia: culverts.

A culvert crisis in our waterways

Freshwater ecosystems are one of the most heavily impacted by human activities.

Many freshwater species, such as the iconic barramundi, start their life as larvae in estuaries, then as small juveniles they make mammoth upstream migrations to freshwater habitats. In fact, about half of the freshwater fish species in south-east Australia need to migrate as part of their life cycle.

When fish are unable to pass human-made barriers, the decline in populations can be huge. For example, in the Murray-Darling Basin where there are thousands of barriers and flows are highly regulated, native fish numbers are estimated to be at only 10% of pre-European numbers.

In New South Wales alone, there are more than 4,000 human-made barriers to fish passage. Over half of these are culverts. Culverts are most often installed to allow roads to cross waterways. They are designed to move water under the road, which they do quite efficiently, but often with no consideration of the requirements of the animals that live there.

When a stream enters a culvert, the flow can be concentrated so much that water flows incredibly fast. So fast, in fact, that small and juvenile fish are unable to swim against the flow and are prevented from reaching where they need to go to eat, reproduce or find safety.

Many current design 'fixes' come with problems

The problem culverts pose for fish is now well acknowledged by fisheries managers, and as a result efforts to make culverts fish-friendly are now widespread.

Where space allows, these new fish passage solutions can resemble a natural stream, where rocks of various sizes are added to break up the flow. Alternatively, artificial baffles (barriers to break up and slow the flow) are also commonly attached to the walls of the tunnel.

These designs do have some drawbacks. They may suit some fish sizes and species, but not all. They can be expensive to install. They also tend to catch debris, which increases maintenance costs and the risk of flooding upstream during high flow events.

BELOW: Most native fish would be unable to move past this road culvert under most flow conditions.

IMAGE: MATTHEW GORDOS

IMAGE: NICOLAS RAKOTOPARE

Using physics to find a new solution

We took a new approach that harnesses a property of fluid mechanics that scientists call the "boundary layer". When a fluid moves over a solid surface, friction causes the water to slow down next to the surface. This thin layer of slower-moving water is called the boundary layer.

Where two surfaces meet, such as in the corner of a square culvert, the boundary layers of the bed and wall merge. This creates a small area of slower-moving water – the "reduced velocity zone" – right in the corner. This is quite small, but little fish can still use it and are very good at finding it.

We wanted to expand this zone (to accommodate a wider range of fish sizes) and slow the water in it further.

So, we added a third surface, generating three boundary layers that then joined. This was done by adding a square beam running the length of the channel wall, close to the floor. The boundary layers of the floor, wall and bottom surface of the beam merged to create a reduced velocity channel along the side of the main flow. The reduced velocity zone is revealed by adding a fluorescent dye, which lingers in the slower flowing water under the square beam we added to the channel.

Testing our design in a 12-metre channel (or flume) found that water moved up to 30% slower in the zone below the beam. For small fish, this is a huge reduction.

In tests, we focused on small-bodied species, or juveniles of larger growing species, because these are considered the weakest swimming size class and most vulnerable to high water velocities created within culverts. Every species tested saw significant improvements in their ability to swim and traverse up the channel.

All of the species benefited, regardless of their body shape or swimming style.

Creating a slower-flowing zone

Our novel fish passage design is highly effective, yet very simple. It's a square beam installed along the length of a culvert wall, so it's easy to incorporate into new structures and cheap to retrofit into existing culverts. It is also much less likely to trap debris than baffles or rocks embedded in the floor of a culvert.

This is a totally new approach that has the potential for widespread application, helping to restore the connectivity of freshwater fish populations here in Australia, and overseas.

More research lies ahead. We're hoping that by optimising the dimensions of the beam we can get even more fish through the channels, with even greater ease. We're also planning field testing to check our laboratory findings work in the real world.

Freshwater biodiversity is greatest in the tropics. Here, developing countries are having drastic impacts on their freshwater ecosystems. The simplicity of this design may make it an affordable approach to help maintain and restore habitat connectivity in developing regions.

Matthew Gordos from NSW Fisheries contributed to this article.

This article first appeared in The Conversation and is kindly reprinted with their permission.

Read more:

Watson, J. R., Goodrich, H. R., Cramp, R. L., Gordos, M. A., & Franklin, C. E. (2018). Utilising the boundary layer to help restore the connectivity of fish habitats and populations. *Ecological Engineering*, 122, 286–294. http://doi.org/10.1016/j.ecoleng.2018.08.008

For further information

Jabin Watson
jabin.watson@uq.edu.au

IMAGE: JAANA DIELENBERG

ABOVE: A fish swimming in the low velocity area created where three boundary layers merge.

BELOW: Jabin Watson inspects an Australian lungfish.

IMAGE: NICOLAS RAKOTOPARE

Self-fumigating birds and manna from heaven: **The remarkable forty-spotted pardalote**

IMAGE: FERNANDA ALVES

ABOVE: A forty-spotted pardalote.

The forty-spotted pardalote has suffered severe range contraction. Although once widespread in Tasmania, this endangered bird is now largely confined to two south-eastern Tasmanian islands, Bruny and Maria. To add to pardalote woes, the larvae of a fly parasite that feeds on the blood of nestlings has been compromising its breeding success. However, researcher **Fernanda Alves**, from the Australian National University, has some good news. She reports on experiments that encourage forty-spotted pardalotes to 'self-fumigate' their nests by incorporating chicken feathers treated with a bird-safe insecticide. Fernanda takes up the story.

The forty-spotted pardalote (*Pardalotus quadragintus*) is a small olive-green bird with a short bill, which is endemic to Tasmania. It is one of Australia's rarest birds, and by far the rarest pardalote. Its range is naturally restricted as it can only live in habitat where white gum (*Eucalyptus viminalis*) is the dominant or sub-dominant species. Forty-spotted pardalotes are foliage gleaners, which means that their feeding strategy consists of plucking invertebrates from foliage. They feed on arthropods, lerps (crystallised honeydew produced by the larvae of psyllids as a protective cover) and manna, a sugary exudate produced on the foliage of white gums.

Manna from heaven – or from white gums

Manna is the most important food item in the diet of pardalote nestlings. Previous research conducted at the Australian National University (ANU) showed that pardalotes can 'farm' white gum manna – they are the first Australian bird that has been found to deliberately cause trees to produce manna. They do this using their bills to clip the stalks of leaves of the white gum. The tree proceeds to exude its nutritious gum over the next few days, which the birds then return to harvest. This ecosystem engineering of the forty-spotted pardalote not only feeds its young but may also play an important role for many other animals in these woodlands.

Range contractions

Historically, the forty-spotted pardalote was widely distributed across Tasmania, but it is now believed to be extinct in most of its range. Its decline and range contraction has resulted in the current listing of the species as Endangered under Australian law. It is now mainly found on two small islands off Tasmania's southeast coast, Bruny and Maria.

The cause of this range contraction is likely a number of threats in combination. Among these are habitat loss and degradation, fire, and aggressive competitors, such as noisy miners. The loss of hollow-bearing trees has been critical, as the forty-spotted pardalotes nest in tree hollows, where they build a dome-shaped nest out of bark and grass, lined with feathers or fur.

IMAGE: FERNANDA ALVES

ABOVE: The research is improving the survival of forty-spotted pardalote chicks by protecting them from a fly parasite.

A gory business

In 2012, an ANU researcher discovered that a fly parasite could be a threat to the forty-spotted pardalote. The ectoparasitic fly *Passeromyia longicornis* parasitises nestlings of forty-spotted pardalotes, causing severe mortality. The fly lays its eggs in the nests of forty-spotted pardalotes and once the nestlings hatch, the larvae burrow under their skin and feed on their blood.

Forty-spotted pardalotes usually nest in tree hollows, but also use nest boxes. This has allowed the research team to monitor them in nest boxes set up on North Bruny Island and to trial solutions. They found that fumigating nest boxes with bird-safe insecticide (pyrethrum) greatly improved the survival of chicks.

The allure of a chicken feather

The natural tree hollows that forty-spotted pardalotes use for nesting are generally high in the canopy and very inaccessible to the average conservation manager. Manually fumigating large numbers of nests is simply not feasible. So how do you get the insecticide into the nests? You get the birds to do all the hard work by tempting them with soft feathers. As forty-spotted pardalotes love to line their nest with soft feathers, they will carry them back into their nests.

The researchers have left out piles of sterilised chicken feathers that are treated with the bird-safe insecticide, and the birds collect them and take them back to line their nests. The results from this 'self-fumigation' technique so far are giving cause for hope. The sight of a tiny pardalote, about the size of a matchbox, flying through the forest with a white feather, which is sometimes bigger than it is, is also quite entertaining.

Next up: Back to the Tasmanian mainland?

A next stage in the conservation of forty-spotted pardalotes will be a full investigation of the prospect of reintroducing them to the main island of Tasmania. I am investigating a range of factors in order to develop a feasibility plan for reintroducing individuals to parts of their historical range.

ABOVE: Researcher Fernanda Alves watches the action inside a nest box caught by a remote camera.

This will include identifying the areas where forty-spotted pardalotes could be translocated to create insurance populations and increase the likelihood of the species' persistence.

Identifying locations will involve mapping the remaining white gum habitat on mainland Tasmania using remote sensing techniques and species distribution models. We will follow this mapping with on-ground surveys to identify the best available habitat on Tasmania – and possible suitable sites for translocation trials. I'm also looking at how changes in habitat quality can affect the distribution and abundance of the species and will then test tools to improve habitat quality.

This Endangered woodland bird may not yet be out of the proverbial woods, but our research is giving us good reason to hope for its future prospects.

For further information

Fernanda Alves
fernanda.alves@anu.edu.au

ABOVE: Sterilised chicken feathers treated with a bird-safe insecticide hang in a dispenser in the forest. Forty-spotted pardalotes are collecting the feathers and flying them back to their nests. In following this natural instinct, they have no idea that they are protecting their chicks from parasites.


Painted honeyeater


Superb Parrot


Male south-east hooded robin

Trending now: The new Threatened Species Index for Australian birds

We are familiar with indices like GDP and the ASX indicating trends in the state of the Australian economy. But what about trends in the state of our environment? An exciting new tool called the Threatened Species Index offers a window into how threatened species are faring and if our collective conservation efforts are stacking up for imperilled wildlife. The index has been made possible through unprecedented collaboration and data-sharing by over 40 research partners led by The University of Queensland, working closely with BirdLife Australia. Project co-leader **Dr Elisa Bayraktarov** outlines the significance of the index and some of the powerful ways it can be used.

ABOVE: Launch of the Threatened Species Index for Australian birds on 27 November 2018 at the Ecological Society of Australia conference in Brisbane. From left to right: Elisa Bayraktarov (UQ), Glenn Ehmke (BirdLife Australia), Hugh Possingham (The Nature Conservancy), Darren Grover (WWF), Sally Box (Department of the Environment and Energy), Brendan Wintle (University of Melbourne), Ayesha Tulloch (Sydney University), James O'Connor (BirdLife Australia).

Australia has over 1800 threatened species. Although monitoring data is available for many of these species individually, until now there has been no way to bring it all together. With many partners, the Threatened Species Recovery Hub has risen to this challenge by creating Australia's first Threatened Species Index (known as the TSX).

The index is unique in that it compiles all available monitoring data to tell us how our threatened species are doing overall, and also which groups (e.g., shorebirds) or regions need more attention.

Locating and assembling the data is a huge undertaking, and has involved extensive collaboration with all state and territory governments and many other conservation and research organisations. In addition, there are more than 200 Friends of the Index who are supporters, potential end-users, or simply people who care about threatened species and want to know more about the index.

Ultimately the index is capable of compiling data for all threatened species in Australia, from orchids to tree-kangaroos.

As a start, we have collected and compiled all available bird data to create Australia's first threatened bird index. Planning is underway for mammal and plants indices.

Creating the index

The statistical approach is modelled on the Living Planet Index, which was designed by the World Wildlife Fund and the Zoological Society of London. That index tracks changes in global vertebrate populations over time, and is used to report against international targets. It compiles data from published scientific literature to track the relative population abundance of thousands of mammals, birds, fish, reptiles and amphibians around the world.

The Living Planet Index has published results every two years since it was initiated in 1998. It was most recently published in October 2018 and showed that on average global vertebrate populations have decreased by 60% between 1970 and 2014. However, for all its value as an international reporting tool, very few Australian threatened species are included in the Living Planet Index – only 24 mammals and seven birds. That is because most data on threatened species in Australia are never published. Rather, they exist as raw data on people's computers, in the reports of recovery teams and in state or territory government repositories. That is why collaborating directly with the groups who undertake monitoring in Australia was so important to our project. It enabled us to assemble data from over 500,000 individual surveys and 35 monitoring programs just for the birds.

Turning this data, which came in many formats, into a dynamic index was a huge undertaking. The Zoological Society of London helped us to adapt the method of the Living Planet Index.

The Terrestrial Ecosystem Research Network, together with the Research Computing Centre of The University of Queensland and a web-app development company called Planticle helped us to develop an automated scientific workflow to streamline data processing. And BirdLife Australia are hosting the raw data and the Threatened Bird Index component of the overall index.

Tracking trends

The index works not by showing population numbers themselves, but by showing the average change in populations compared to a base year. It currently includes data for 43 species and subspecies of bird, which represents about 30% of all nationally listed threatened birds.

The base year for the index has been set at 1985, which gets a score of one. A score of 1.2 would indicate a 20% increase on average in numbers of threatened birds, while a score of 0.8 would indicate a 20% decrease on average since 1985.

The index shows us that between 1985 and 2015 the numbers of the 43 threatened species and subspecies decreased by 52% on average – see Figure 1. There is some variation among individual species within this multi-species index. The grey cloud indicates the variability between the trends for individual birds that build the composite.

One of the most exciting and powerful features of the Threatened Species Index is the ability to look at results for groups of birds, for example, shorebirds, or for regions, like Queensland – or both, for example, Queensland shorebirds.

Figure 2 shows the results when we select shorebirds. The index shows that their numbers have decreased by 72% on average over the past 30 years. The diagnostic tools tell us that this index is based on six species and subspecies, with good coverage for most of Australia's coastline except for the Northern Territory.

But the Threatened Species Index is not all bad news! For example, if we drill down to produce an index for Victoria's threatened birds, we obtain an index on 18 species and subspecies whose numbers decrease between 1985 and 2000 but then stabilise (Figure 3). This is where recovery actions may have kicked in and led to some successes.

Over to you

You can explore and use the index at **tsx.org.au.** It is a dynamic tool to which more data will be added as they become available and are verified. And the more data, species and regions that are added, the more powerful, meaningful and representative the index will become.

We are always on the lookout for good additional data. If you have data spanning multiple years on threatened or near-threatened Australian bird species and subspecies, we'd be delighted to hear from you.

Australia's Threatened Species Commissioner Dr Sally Box launched the Threatened Species Index on 27 November 2018 at the Ecological Society of Australia conference in Brisbane.

For further information

Elisa Bayraktarov
e.bayraktarov@uq.edu.au

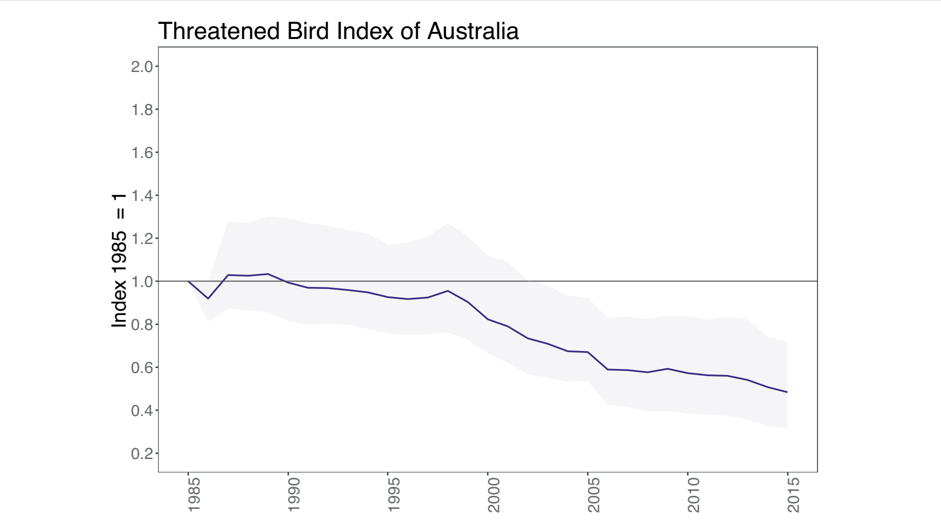

Figure 1: Between 1985 and 2015, the 43 threatened species and subspecies decreased by 52% on average.

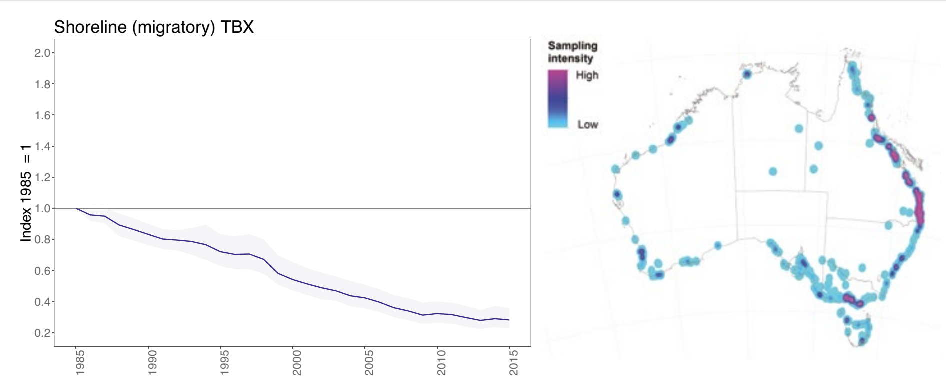

Figure 2: There has been a 72% decrease in shorebirds over the past 30 years.

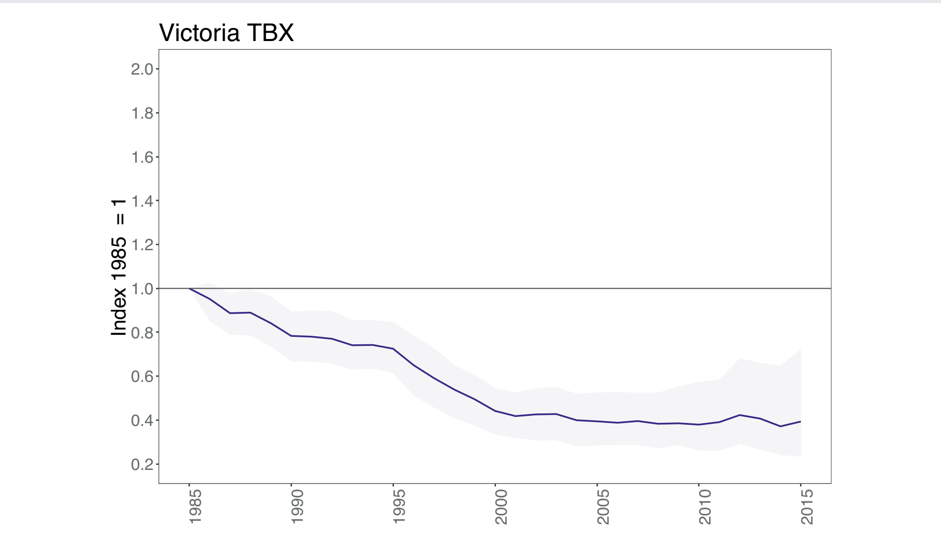

Figure 3: Recovery actions may be behind the stabilisation since 2000 of numbers of threatened birds in Victoria.

TSR Hub
Researcher Profile

IMAGE: GEORGIA GARRARD

IMAGE: GEORGIA GARRARD

Georgia Garrard
Connecting people with biodiversity

ABOVE LEFT:
The elusive spiny rice-flower.

After undergraduate majors in Geography, Environmental Science and Botany, I did my PhD on native grasslands. I was struck by how these Critically Endangered ecosystems existing right on the edge of my city were being lost without most people even knowing about them – or understanding what amazing, superdiverse ecosystems they are. They are not the brown, dead, snake-infested paddocks of popular imagination but rather home to an abundance of incredible plants and animals (e.g., striped legless lizard, earless dragon, plains wanderer).

My PhD looked at how much effort was needed to achieve confidence that threatened grassland species present at a site would be detected in surveys. I showed that the effort typically put into environmental impact assessments at proposed development sites was nowhere near enough. Because the proponents of new developments do not necessarily want to find any threatened species on their land, it makes sense for policy to specify minimum survey effort requirements. As a consequence of my work, these requirements now inform the Significant Impact Guidelines for the spiny rice-flower (*Pimelea spinescens* subsp. *spinescens*) under the EPBC Act.

Humans and biodiversity

My research has increasingly focused on the human elements of conservation. Because cities are first and foremost human environments, it's impossible to ignore people in urban conservation decisions.

But cities are also really important for conservation, and home to many of Australia's most threatened species and ecosystems. My work on Biodiversity Sensitive Urban Design (BSUD) sought to reconcile the needs of residents, planners and developers with the requirements of native species and ecosystems to create a model for cities as places for both people and biodiversity.

There's a lot to be said for having more diverse native vegetation around our homes. I live in Castlemaine in regional Victoria and, for me, the striking difference between Melbourne and Castlemaine is the diversity of native vegetation. People's yards are bigger in Castlemaine and include native grasses, shrubs and trees. The birdlife is amazing – eastern spinebills, mistletoebirds, brown thornbills, silvereyes and scrub wrens are all regular visitors to our yard. More nature in cities can deliver a huge range of benefits, from cooling and reduction in the urban heat island effect to health and wellbeing benefits like reduced risk of heart disease, lower stress levels, increased social cohesion, better sleep. Emerging research has shown that many of these benefits are improved when that nature is biodiverse.

Fostering engagement

My work with the hub focuses on understanding why people may not be engaging with threatened species and biodiversity conservation and how best to (re)engage them. There's many reasons for disengagement. For some, the sense of loss and hopelessness can be overwhelming and disempowering. For others, the links between biodiversity and our own lives (and therefore the things that we can do to improve biodiversity) are not clear. Many people are time-poor, and this is where the everyday, incidental contact with nature that we aim to achieve with BSUD becomes so important.

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Editor: Jaana Dielenberg
j.dielenberg@uq.edu.au

Science Communication Officer: Kate Donnelly

Graphic Design: Mary Cryan

www.nespthreatenedspecies.edu.au

COVER IMAGE: JABIN WATSON INSPECTS AN AUSTRALIAN LUNGFISH (SEE PAGE 10 FOR THE FULL STORY). IMAGE: NICOLAS RAKOTOPARE

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